

A new bourgueticrinid (Crinoidea) from the Castle Hayne Formation (Eocene) of southeastern North Carolina, USA

CHARLES N. CIAMPAGLIO¹, STEPHEN K. DONOVAN^{2*} & PATRICIA G. WEAVER³

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ABSTRACT

Cenozoic fossil stalked crinoids are poorly known. Based on a large, new collection of disarticulated columnals and cups, a new gracile bourgueticrinid, *Democrinus simmsi* species nov., is described from the Eocene Castle Hayne Formation as exposed at the Martin Marietta Quarry, New Hanover County, southeastern North Carolina (USA). The smooth, conical cup of *D. simmsi* commonly is widest at the oral surface, moderately flared orally in small (juvenile?) specimens, but tends to be subcylindrical in larger examples. The basals

are at least 1.5 times the height of radials. Some columnals of mesistele and dististele have distinctly warty latera. This is the first nominal bourgueticrinid from the Paleogene of North America, despite their moderate diversity locally in the Paleogene of Eurasia. The small size of cups and disarticulated columnals of gracile bourgueticrinids are almost certainly a factor in our poor knowledge of their fossil record.

Introduction

The Middle Eocene Castle Hayne Formation of North Carolina is well known for its abundant and diverse echinoderm fauna (Emmons 1858; Kellum 1926; Cooke 1959; Kier 1980; Carter et al. 1988; Ciampaglio & Weaver 2004). While previous research has focused on the echinoids (e.g. Cooke 1959; Kier 1980), a systematic survey of the crinoid fauna has only recently been initiated (Ciampaglio & Weaver 2004). This is undoubtedly due, in part, to the disarticulated nature of crinoid fossils, and the difficulty of isolating, recognizing and identifying individual elements, all of which have discouraged taxonomic studies. Although several species of comatulid crinoids have been described from the Castle Hayne Formation (Emmons 1858; Ciampaglio & Weaver 2004), its stalked forms have been largely overlooked. Careful examination of a prepared bryozoan-echinoid calcirudite from the Martin Marietta Quarry near Castle Hayne, New Hanover County (North Carolina, USA), has yielded over 1,000 specimens, mainly cups and columnals, of a new species of gracile bourgueticrinid.

Geological setting and stratigraphy

The outcrop of the Middle-Upper Eocene Castle Hayne Formation is between 16 and 32 km wide, and extends from Brunswick County and New Hanover County north through east-central Pender County, through western portions of Onslow, Jones and Craven counties, and into southeastern Pitt County in southeastern North Carolina (Otte 1986) (Fig. 1). Bounded by unconformities above and below, the formation is typically overlain by Oligocene and younger rocks, and underlain by Paleocene and Cretaceous deposits. The Castle Hayne Formation is thought to range from middle Lutetian to Priabonian in age (Harris & Laws 1997).

Baum et al. (1978), Ward et al. (1978), Kier (1980), Zullo & Harris (1986, 1987) and Harris & Zullo (1987) have all interpreted the lithostratigraphic subdivisions of the Castle Hayne Formation (Fig. 2). Ward et al. (1978) named three lithosomes within the limestones of the formation; in ascending order, the New Hanover, Comfort and Spring Garden members. The first is a slightly arenitic, micritic and phosphatic lithocalcirudite; the Comfort Member (middle) is a grey- to cream-coloured,

¹ Department of Geology, Wright State University, Lake Campus, 7600 SR 703, Celina, Ohio 45822-2952, USA.

² Department of Geology, Nationaal Natuurhistorisch Museum, Postbus 9517, NL-2300 RA Leiden, The Netherlands.

³ North Carolina State Museum of Natural Sciences, 11 West Jones Street, Raleigh, North Carolina 27601-1029, USA.

* Corresponding author: S.K. Donovan. E-mail: donovan@naturalis.nnm.nl



Fig. 1. The outcrop of the Middle-Upper Eocene Castle Hayne Formation (in grey) in North Carolina (USA), with the location of the Martin Marietta Quarry.

bryozoan-echinoid calcirudite, grading into a fine calcarenite; and the uppermost unit is a tan to grey, arenaceous, molluscan-mould biocalcirudite. All units are typically diachronous.

Applying a sequence-stratigraphic approach, Harris & Zullo (1987) divided the Castle Hayne Formation into five depositional sequences (numbered 0–4). These sequences, separated by regional unconformities, reflect changes in sea-level and migrating depositional environments. A complete lithologic section consists of a phosphate pebble biomicrudite base overlain by biosparudite, in turn overlain by biomicrudite grading into biosparudite. However, this complete lithostratigraphic section is rarely seen at a single locality and sequences are typically represented by different lithologies at various exposures.

Using an echinoid-based biostratigraphic approach, Kier (1980) divided the Castle Hayne Formation into three informal biozones (early, middle, late). These temporal biozones overlap somewhat with the depositional sequences defined by Harris & Zullo (1987), and provide a reasonable biostratigraphic interpretation. Correlation between sequence stratigraphy (Harris & Zullo 1987), biostratigraphy (Kier 1980) and lithostratigraphy (Ward et al. 1978) is provided in Figure 2. Stratigraphic location of bourgueticrinids within the Castle Hayne Formation is not precisely known, but based on the location in the quarry where the specimens were collected, coupled with the presence of the echinoid *Periarchus lyelli*, it is likely that the crinoids documented herein stem from sequences 3 or 4 of Zullo & Harris (1987).

Interpretation of the environment in which the Castle Hayne Formation was deposited is complicated by several factors, including the presence of formation outliers throughout the southern coastal plain, the abruptly changing thickness of

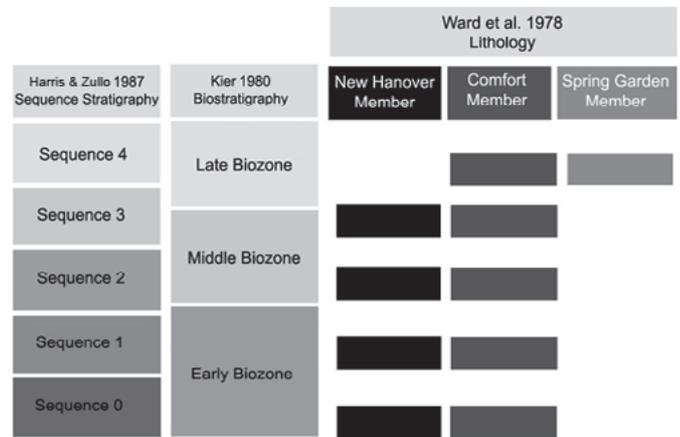


Fig. 2. Correlation between sequence stratigraphy (Harris & Zullo 1987), lithostratigraphy (Ward et al. 1978) and biostratigraphy (Kier 1980) of the Castle Hayne Formation (after Ciampaglio & Weaver 2004: fig. 1). The New Hanover, Comfort and Spring Garden members are time transgressive and do not occur in all depositional sequences, essentially forming a ‘fining-upwards’ lithology in each depositional sequence in which they occur.

the formation from one exposure to another and the isolation of outcrops (Otte 1986). Nevertheless, stratigraphic analysis has produced a fairly clear picture of the history and environment in which these carbonates were deposited (Gibson 1970; Jones 1983; Otte 1986; Zullo & Harris 1986; Harris & Laws 1997). Sea level rise during the Middle Eocene, coupled with a productive, relatively warm-water environment, allowed for the development of limestones of the Castle Hayne Formation (Gibson 1970; Otte 1986; Harris & Laws 1997). The presence of fossiliferous, mollusc-bearing outliers as far west as Wake County indicate that the warm Eocene sea extended at least that far ‘inland’ (Richards 1950; Carter et al. 1988). The depositional basin was formed by differential movement of fault-bounded crustal blocks, which also controlled thicknesses and distributions of carbonate lithofacies of the strata assigned to the formation (Jones 1983). The Middle Eocene sea floor of North Carolina was composed of shoreline-parallel environments that define the inner (0–15 m water depth), middle (15–50 m) and outer shelves (50–100 m). Depositional environments were in an open, relatively warm-water embayment that paralleled the present-day shoreline (Jones 1983; Otte 1986).

Materials and methods

Cream-coloured, bryozoan-rich matrix was collected from abundant spoil piles in the Martin Marietta Quarry, Castle Hayne, New Hanover County, North Carolina. All matrix was screened through a 6 mm mesh to remove large clasts and fossil fragments. The remaining matrix was then screened through a 0.8 mm mesh, to remove silt and small fragments, and then washed in tap water to remove remaining silt or clay. Once

thoroughly dried, prepared matrix was examined under magnification in order to isolate and pick crinoid specimens. All figured specimens were mounted and sputter-coated with gold/palladium using an Anatech Hummer V sputter coater. Once coated, all figured specimens were examined and photographed using a Philips XL 30 ESEM TMP scanning electron microscope (SEM).

Systematic palaeontology

Morphological terminology of the crinoid endoskeleton used herein follows that of Moore et al. (1968, 1978) and Ubaghs (1978). Classification of the articulate crinoids follows Simms and Sevastopulo (1993), Simms et al. (1993) and Cohen et al. (2004). Specimens described herein are deposited in the North Carolina State Museum of Natural Sciences (NCSM).

Class Crinoidea MILLER 1821

Subclass Cladida MOORE & LAUDON 1943

Infraclass Articulata MILLER 1821

Order Comatulidina CLARK 1908

Family Bourgueticrinidae DE LORIOLE 1882

Bathycrinids

Discussion. – Simms et al. (1993: 503) subsumed the four bourgueticrinid families recognized by Rasmussen (1978) in the family Bourgueticrinidae, arguing that “Their separation into distinct families almost certainly results in the creation of paraphyletic taxa.” Bathycrinids are retained herein as a grade of organization rather than a Linnean systematic division per se. For fuller discussion of the family Bathycrinidae BATHER 1899, see Rasmussen (1978: T843T846). Current questions of bourgueticrinid relationships were discussed by Jagt (1999).

Genus *Democrinus* PERRIER 1883

1912 *Rhizocrinus* (*Bythocrinus*) – Döderlein: 4, 11.

Type species. – *Democrinus parfaiti* PERRIER 1883, by monotypy (Rasmussen 1978: T844).

Diagnosis. – After Rasmussen (1978: T844): “Cup variably slender conical, cylindrical, or fusiform, composed of 5 very high, slender basals forming greater part of cup and superposed by 5 short radials surrounding narrow central canal. Sutures distinct. Radial articular facets large. Articulation of basal cirlet with top of stem smooth and circular, with diameter corresponding to base of cup. Growth of cup mainly affects basal cirlet, height increasing more than width, mature specimens attaining slender, more cylindrical form. Interradial nerve canal extends from basals in sutures between radials before dividing. Arms 5, undivided. Every second brachial articulation is synostiosial, synarthrial, or trifascial. Synostiosial articulations may be modified, a short median ridge from axial canal to dorsal edge of proximal articular facet fitting into a furrow in distal face of preceding brachial. Few (generally less

than 6) low proximal columnals have synostiosial articulations. More distal columnals resemble those of other Bathycrinidae.”

Discussion. – Of the other bathycrinid genera listed by Rasmussen (1978), *Bathycrinus* WYVILLE THOMSON 1872 has low basals and a broadly conical cup with a broad radial cavity; *Conocrinus* D’ORBIGNY 1850 has high basals which may overgrow radials and proxistele, but the cup is strongly vase-like, widest below the radial facets; *Dunnocrinus* MOORE 1967 and *Monachocrinus* CLARK 1917 have conical cups in which radials and basals are about equal in height; and *Rhizocrinus* SARS 1868 has basals slightly higher than radials, but sutures of the cup are fused.

Democrinus simmsi sp. nov.

(Figs. 3, 4)

2004 *Democrinus* sp. – Ciampaglio & Weaver: 179.

Types. – Holotype, NCSM 9582, cup (Fig. 3b). Paratypes, NCSM 9583-9590 (all cups), NCSM 9591 (pluricolumnal), NCSM 9592-9602 (columnals).

Type locality and type horizon. – All types and other specimens from Martin Marietta Quarry, Castle Hayne, New Hanover County, North Carolina (Kier 1980: 13–14, figure 1). Castle Hayne Formation, probably sequence 3 or 4 of Zullo & Harris (1987), Middle Eocene.

Etymology. – For Dr. Michael J. Simms, in recognition of his contributions to the systematics and phylogeny of stalked articulate crinoids.

Diagnosis. – *Democrinus* with smooth, conical cup, widest at oral surface, moderately flared orally in small (juvenile?) specimens, but tending towards subcylindrical in larger examples. Basals at least 1.5 times height of radials. Some columnals of mesistele and dististele with strongly warty latera.

Material examined. – Six lots of specimens. NCSM 9603, 59 columnals, many with warts on latera; NCSM 9604, 164 columnals from the dististele and mesistele (plus one brachial?); NCSM 9605, 33 columnals; NCSM 9606, 124 columnals; NCSM 9607, 121 cups and six basal plates; and NCSM 9608, 1069 columnals, four cups and a basal plate, plus one cirral ossicle (comatulid), eight brachial ossicles, three ophiuroid vertebral ossicles, seven astropectinid marginal ossicles, a fragment of echinoid spine and 19 indeterminate ossicles. A further brachial mounted for SE microscopy, NCSM 9609. The brachial ossicles are wider than even the largest known radial facet of *D. simmsi* and are probably derived from comatulids (Ciampaglio & Weaver 2004); they are not considered further herein.

Description. – Column slender, xenomorphic. Proxistele not known, but base of cup has a small, central, pentagonal lumen,

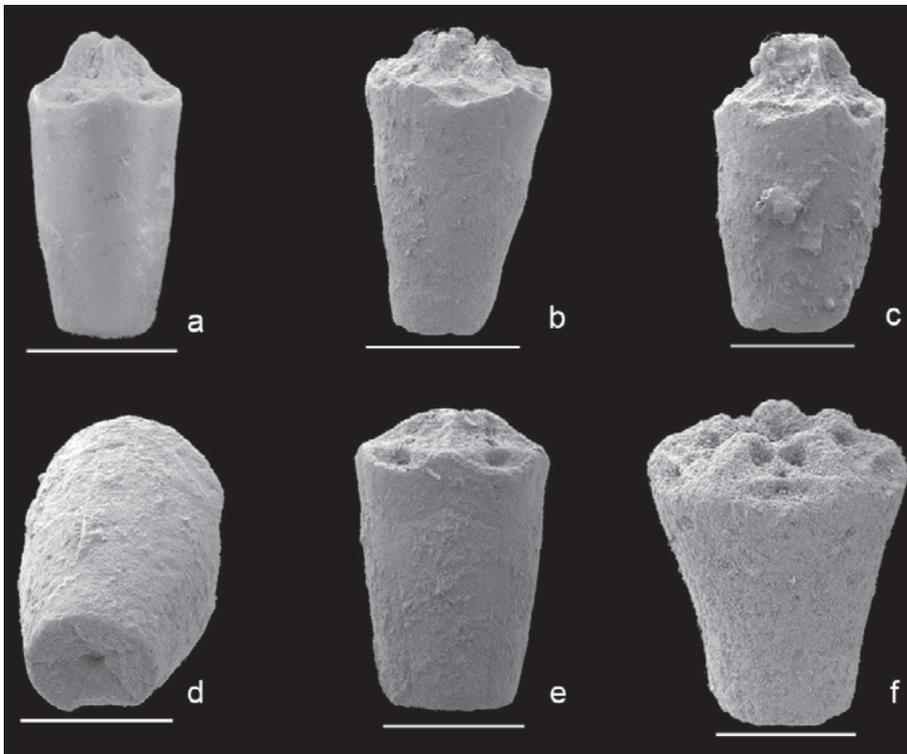


Fig. 3. *Democrinus simmsi* n. sp., cups in lateral view (except d). a) NCSM 9587, large specimen. b) NCSM 9582, holotype. c) NCSM 9585. d) NCSM 9583, basal view showing sutures between basal plates. e) NCSM 9589. f) NCSM 9588, small specimen, close in morphology to juvenile bourgueticrinids from the upper Campanian of north-east Belgium (Jagt 1999: pl. 30, figs. 1–3; J.W.M. Jagt, pers. comm. 2006). All paratypes unless stated otherwise. SEM pictures. Scale bars: 0.5 mm (f); 1 mm (b–e); 2 mm (a).

a syzygial articular facet and five radial grooves, corresponding to sutures between basal plates (Fig. 3d). All known columnals are from the mesistele and dististele, generally are higher than wide and have synarthrial articulations. Articular facets more or less elliptical and strongly divergent within columnals, with synarthrial fulcra corresponding to long axes of articular facets, at about 80° to each other in all columnals. Synarthrial ridges flanked by fine, unbranched, tooth-like crenulae arrayed perpendicular to the long axis of the fulcra (Fig. 4c). Articular facet around fulcrum conical, with a central depression shaped like the figure ‘8’, with lumen at the bottom. Columnals of mesistele barrel-shaped, with a latus that is either unsculptured or with more or less irregularly shaped warts in close association. Columnals of dististele less barrel-shaped and more T-shaped or vase-like in lateral view, with small, circular, radicular facets on latus at either end of each fulcrum and adjacent to the articular facet; latus sculpture as mesistele. Attachment structure not preserved.

Cup dicyclic, conical in small (juvenile?) specimens, becoming more subcylindrical in larger examples, widest at the oral surface or just below it; the former may be slightly flared at oral surface. Five tall basal plates support five shorter radials. Latera planar, unsculptured, plate sutures more or less apparent. Articular facets of radials full width of plate and angled away from oral surface, surrounding narrow central cavity; articulation synarthrial. Arms and brachials unknown.

Discussion. – The variations seen in cups (Fig. 3) and colum-

nals (Fig. 4) make splitting these specimens into more than one species a great temptation. However, the stems of modern bathytrichids are well known (Donovan 1997), permitting confident separation of columnals of mesistele and dististele, and the variation in cup geometry within gracile bourgueticrinid species can be considerable (Kjaer & Thomsen 1999). Although the lack of recognizable arms is unfortunate, as there is a wealth of cups and columnals with which to define the species, providing more than sufficient morphological information to enable erection of this new taxon. The lack of surface irregularities on any cup indicates that the warts on some columnals are not an artifact of diagenesis; they are reminiscent of some of the structures seen on some ossicles of the attachment structure in late Maastrichtian *Dunnicrinus aequalis* (D’ORBIGNY 1841) (see Jagt et al. 1998) and the columns of some other bourgueticrinids (Jagt & Odin 2001: pl. 1, fig. 11).

Democrinus simmsi is easily differentiated from other Paleogene bourgueticrinids. The greatest diversity of Paleogene bourgueticrinids is from the Danian, for which Rasmussen (1961: 412) tabulated six species, four of them bathytrichids. *Bathytrichus windi* RASMUSSEN 1961 (Denmark) has low basals, high radials and a kylixiform cup (sensu Warn & Strimple 1977: text-fig. 5g, h); *Democrinus gisleni* RASMUSSEN 1961 (Denmark, Sweden) is low and conical, with basals only a little higher than radials; *D. maximus* (BRÜNNICH NIELSEN 1915) (Denmark, Sweden, Belgium, The Netherlands, former U.S.S.R.) has a barrel-shaped cup that is commonly, but not invariably, constricted just below the oral surface (see also

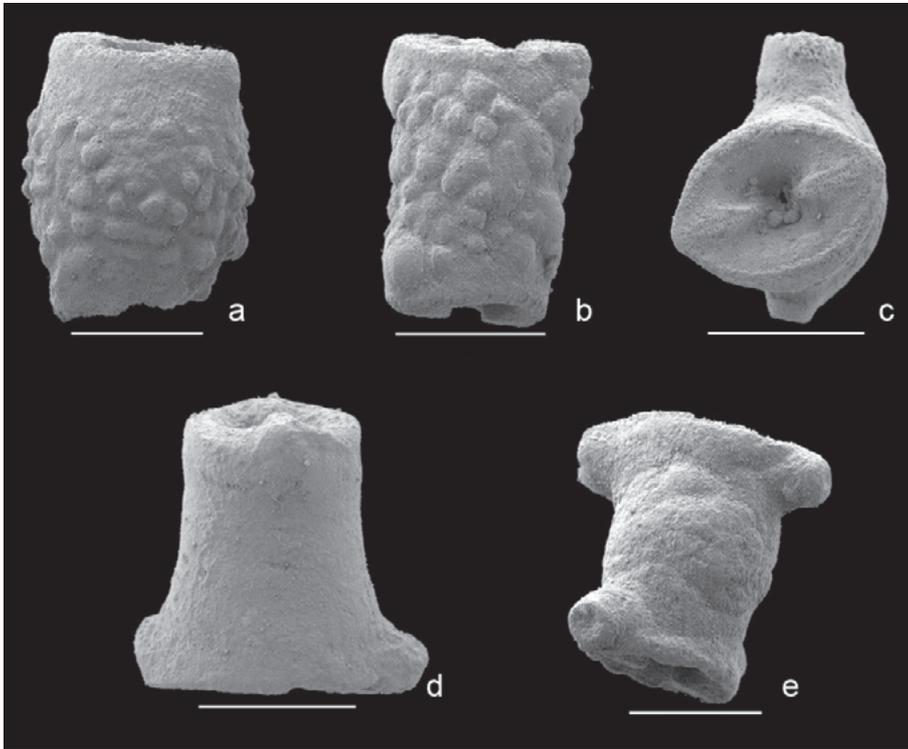


Fig. 4. *Democrinus simmsi* n. sp., paratype columnals from the mesistele (a, b) and dististele (c–e). a) NCSM 9596, warty latus. b) NCSM 9595, warty latus. c) NCSM 9593, articular facet. d) NCSM 9594, lateral view. e) NCSM 9597, oblique lateral view of specimen with irregular latus. SEM pictures. Scale bars: 1 mm.

Klikushin 1982; Kjaer & Thomsen 1999; Jagt 1999: pl. 28, figs 2, 5, 6); *Monachocrinus? regnelli* RASMUSSEN 1961 (Denmark, Sweden, France) has a low, pea-like cup with a rounded base; and both *Bourgueticrinus bruennichiensi* ØDUM 1923 (Denmark, Italy, former U.S.S.R., USA) and *B. danicus* BRÜNNICH NIELSEN 1913 (Denmark, Sweden, Belgium, The Netherlands, former U.S.S.R.) have high, distinctive proximalia (Rasmussen 1972: pl. 1, fig. 8; Klikushin 1982; Kjaer & Thomsen 1999; Jagt 1999). The Ypresian (early Eocene) *Democrinus londinensis* (FORBES 1852) has particularly high basals, "... about three times the height of the radials ..." (Rasmussen 1972: 32) in a conical cup. All of the *Conocrinus* spp. from the Paleocene and Upper Eocene of the Crimea (Klikushin 1982) and Eocene of Biarritz (Roux 1978a, b) are easily differentiated from *D. simmsi* by their more or less strongly barrel-like cups. The columnals of *Palaobathycrinus endelmani* KLIKUSHIN 1982 from the upper Danian and 'Montian' of Mangyshlack, has columnals with a rounded articular facet outline throughout the column.

As noted by Hess (1999: 233), Cenozoic crinoids have a poor fossil record. This is emphasized by the bourgueticrinids, which, away from the Danian (Lower Paleocene) (Rasmussen 1961; Klikushin 1982; Kjaer & Thomsen 1999; Jagt 1999), are rare fossils. Numerous studies have been published on Cenozoic (mainly Paleocene) and Late Cretaceous bourgueticrinids from Western Europe (e.g. Rasmussen 1961, 1978; Jagt 1999; Kjaer & Thomsen 1999), Eastern Europe (Klikushin 1982), Alabama (Clark & Twitchell 1915) and Mississippi (Moore

1967), but Paleogene bourgueticrinids from the southeastern coastal plain have never been published. Further, while Western and Eastern Europe have produced diverse Late Cretaceous and Cenozoic bourgueticrinid faunas, only a few species of fossil bourgueticrinids are known from North America. These include *Democrinus* sp. (Perrier 1883), *Dunnocrinus mississippiensis* MOORE 1967, *Dunnocrinus* sp. (Lauginiger 1988), *Bourgueticrinus alabamensis* DE LORIO 1882 and *Bourgueticrinus bruennichiensi* ØDUM 1923; of these, only *Democrinus* was reported from the Cenozoic. To the very few North American occurrences mentioned above can be added *Democrinus?* sp. columnals from the middle Miocene of Carriacou, the Grenadines (Donovan & Veltkamp 2001) and similar specimens from the early Pleistocene of Jamaica (Donovan 1995). The Pleistocene occurrence probably represents at least one of the extant, gracile bourgueticrinids which occur in the tropical western Atlantic, *Democrinus brevis* (CLARK 1909) and *Monachocrinus caribbeus* (CLARK 1908) (Meyer et al. 1978).

The poor fossil record of the bathycrinids in the Cenozoic of the Americas is certainly, at least in part, due to taphonomic factors coupled with resultant collection failure. Extant bathycrinids are gracile and small, a typical mature adult specimen perhaps being about 100 mm high. Complete crinoids, or even just near-complete crowns, are very rare fossils and it is much more likely for a bathycrinid to enter the rock record as a myriad of small disarticulated ossicles. Collecting such specimens either requires patience and the eye of an expert (the

few bathyrcrinid ossicles known from the Cenozoic of the Antilles were collected this way: Donovan 1995; Donovan & Veltkamp 2001) or an enclosing rock that is poorly lithified and amenable to micropalaeontological processing such as sediment sieving. It is the latter methodology that has enabled the large collection of specimens upon which *D. simmsi* is based to be accumulated from the Castle Hayne Formation.

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